Novel technology provides rapid and reliable outage assessments after natural disasters wreak havoc

March 26, 2019

A team has developed and deployed groundbreaking technology to test the impacts of damage to many specific network components

No cell coverage? No internet access? No heat or air conditioning? We have all experienced a temporary loss of electricity which quickly becomes an annoyance in our modern world accustomed to 24/7 everything.

However living without electricity for a more extended period of time, weeks or months, is a reality for so many after a major natural disaster occurs.

Not having access to modern day necessities for a long period of time impacts individuals' health and safety, impacts the security posture locally and often times nationally, and has far reaching economic implications. When major natural disasters like category 4 or 5 hurricanes hit land, and subsequently bring down the area's electrical grid, every aspect of life is disrupted and severe economic loss can occur.

In addition, with hurricanes Katrina, Sandy and Maria as examples, we are seemingly witnessing an increase in frequency and intensity of natural disasters. Over the last twenty years, technology has dramatically improved the ability to track and forecast the arrival and intensity of natural disasters.

However technology that estimates a disaster's impact on electrical grids, using precise detail in the network modeling, has not existed until now.

A team of Laboratory scientists and researchers has developed and deployed groundbreaking technology to do just that - test the impacts of damage to many specific network components. The Severe Contingency Solver for Electric Power Transmission Systems (SCS-EPT) is the only open-source software that reliably models impacts to electrical grids and computes the maximum number of customers that can be served by the severely damaged grid to ensure reliable operations.

Significance of the work

A power network consists of many components including generators, lines, loads, transformers, shunts and buses that connect to each other in the form of a grid and delivers electrical power to customers. Extreme events, such as natural disasters or planned attacks, cause severe damage to many components in a power network in a very short period of time. If many components are damaged simultaneously and a large amount of power loss occurs, it can be weeks or even months before the affected components are repaired. After hurricane Maria made landfall in Puerto Rico, it took almost one year (328 days) to completely restore power to the debilitated island.

Today, individuals and economies are more dependent on power supply than ever before and natural disasters are a constant threat to populations and power networks. It is critical for network owners and operators, policymakers and government officials to understand where their networks are most vulnerable during an attack. Until now the ability to quantify the impact of damaged network components from these extreme events has been non-existent. The LANL team tackled this seemingly unsolvable problem by creating the open-source software that is just that—a solver.

Computing large ensembles of damage scenarios is desirable in extreme event analysis for quantifying risk and monitoring a broad range of possible vulnerabilities. By developing complex algorithms that quantify the impact of damage on a power network, and specifying how many electrical loads must be dropped and where in order to regain power, SCS-EPT answers the question of impact on the power grid when extreme events occur. For hurricanes, floods, ice storms and earthquakes, SCS-EPT can be coupled with sophisticated natural disaster forecasts and component fragility models in order to compute the maximum amount of power that can be delivered shortly after the event has passed but before repair crews are dispatched.

How does the analysis process work? The basic approach to analyzing the impacts of seasonal hurricanes, is to first run a physics-based simulation of an approaching hurricane to generate wind speed estimates. For each component in a power network, these wind speeds are combined with wind fragility models to generate a number of power network damage scenarios. These scenarios are then fed into the SCS-EPT software to provide a basic understanding of how much load must be dropped from the network in order to restore power after a hurricane event. A similar workflow can be designed for a wide range of other events where disaster forecasts and network asset fragility models are available.

Additionally, SCS-EPT is the only software available today guaranteed to provide a solution for a severely damaged power network or one with hundreds of damage points. It is the combination of cost (free), ubiquity (runs on any operating system) and reliability that makes SCS-EPT the number one choice for all power networks, from smaller utility companies to national government agencies. A guaranteed solution is a valuable algorithmic property because it removes the need for human intervention reducing the time to result from several hours to just a few seconds and increases the number of damage scenarios that can be simulated from just a few to hundreds or even thousands.

Achievements

It took an expert understanding of power networks, mathematical programming and computation to develop SCS-EPT, the product of hard-earned scientific advances in power network mathematics. Previously, the analysis included extremely complicated calculations simulating the nonlinear physics of the grid which were conducted by hand, work that involved 100,000 variables and equations. The Los Alamos team developed new, advanced algorithms making the calculations more reliable and removing the need for human mediation. Not only is SCS-EPT the first software to analyze extreme event damage to a power network, but it is the first to do so reliably, consistently and accurately. Peer-reviewed by field experts, SCS-EPT is currently used by a number of U.S. government agencies. Los Alamos scientists also are called upon by the U.S. government to perform rigorous analytics using SCS-EPT, formally called Crisis Action, when major hurricanes are approaching.

SCS-EPT is open-source software providing critical information during times of power crisis. Written in high-level scientific computing language Julia, anyone can download this software for free, further customize it for their specific needs, employ it to assess the impacts of severe damage on a power network and determine a stable operating condition for the damaged network. Only SCS-EPT allows this type of customization.

SCS-EPT is truly novel. The use of the software is inspiring the development of a new generation of power system analysis tools at Los Alamos National Laboratory. The LANL team is currently working on similar solver capabilities for other sectors including power distribution and gas networks. These new tools will further assist network operators and policymakers to understand and quantify how a power network will respond to extreme events where many components are simultaneously out-of-service. Providing invaluable situational awareness above and beyond commercially available analysis software, SCS-EPT is helping stakeholders better plan for and respond to extreme events. Whether the decision is to mobilize FEMA, dispatch additional repair crews from neighboring areas, or bring in generators for life saving measures, SCS-EPT produces invaluable information and solutions in minutes - a game changer in this field.

The research team: Carleton Coffrin, James Arnold, Scott Backhaus, David Fobes, Kaarthik Sundar and Byron Tasseff of the Information Systems and Modeling group and Russell Bent of the Applied Mathematics and Plasma Physics group.

Publications: McDonald, R. (2019, February). Out of the Dark. 1663, 18-24. C. Coffrin, R. Bent, B. Tasseff, K. Sundar and S. Backhaus, "Relaxations of AC Maximal Load Delivery for Severe Contingency Analysis," in IEEE Transactions on Power Systems, vol. 34, no. 2, pp. 1450-1458, March 2019.

Funding: Department of Homeland Security's National Infrastructure Simulation and Analysis Center (NISAC). U.S. Department of Energy through the Los Alamos National Laboratory LDRD Program and the Center for Nonlinear Studies

This research supports Los Alamos National Laboratory's Global Security and Energy Security mission areas and the Information Science and Technology pillar(s) by proving a new capability for quantifying vulnerability in critical infrastructure systems.

Caption for image below: *Carleton Coffrin, James Arnold and Mary Ewers review the impacts of a disaster scenario using the Severe Contingency Solver.*


NNSA
National Nuclear Security Administration